Συνεργεια

Synergia software and algorithm project

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April 5, 2005

- Physics Topics
  - why we do what we do
- Development Topics
  - what it is we are doing
- Resources
  - who (and what) we have to do it

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Physics topics

- Even more realistic Booster simulations and Proton Driver simulations
  - more sophisticated RF system model, proton driver design
- Beam-beam interactions
  - Tevatron, LHC
- ILC damping ring
  - space charge under very different conditions than the Booster
- Electron cooling/cloud
  - Main Injector, LHC

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Development topics

- Python steering/IMPACT modularization
  - critical part of development plan
- New physics effects
  - beam-beam, impedance, electron cooling/cloud
- Physics algorithms
  - 6D matching, improved RF model
- Analysis/visualization
- Optimization

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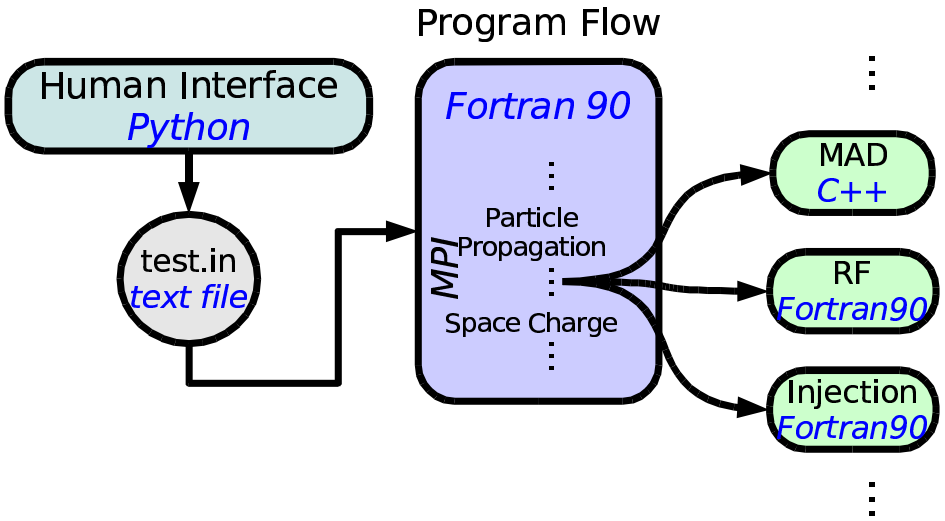
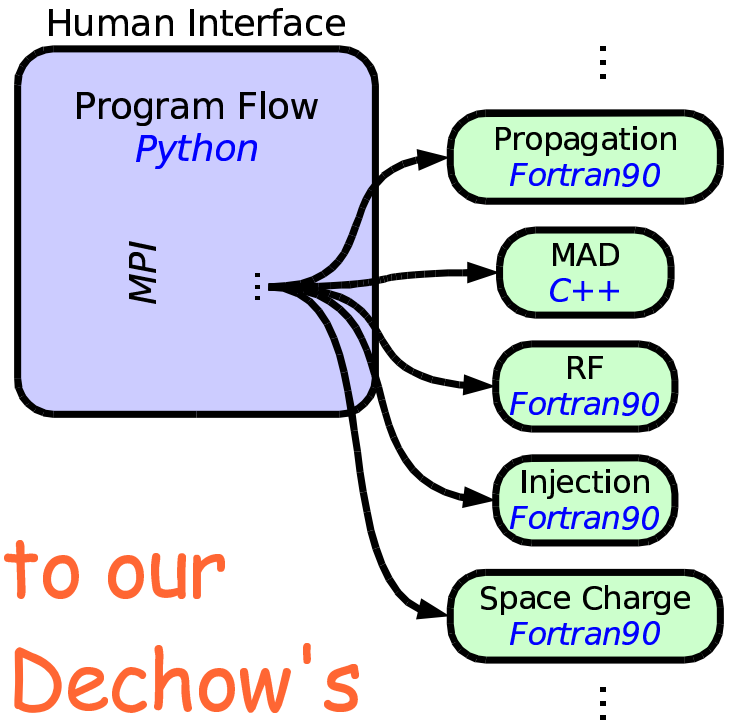
Python steering/IMPACT modularization

old way: inflexible



new way: flexible, extensible



Greater flexibility is central to our development plans. See Doug Dechow's talk for status.

New physics effects

- Beam-beam interactions
  - New hire: Eric Stern
  - Start with existing code, BeamBeam3D
  - Incorporate BeamBeam3D into Synergia when appropriate
    - depends on Python steering/modularization
- Impedance
  - Have code from collaborator, Roman Samulyak (BNL)
    - easy application for Python steering, would be complicated otherwise
- Electron cooling/cloud

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Physics algorithms

- Generating beams optimized for a given accelerator/parameters (matching)
  - 4D (transverse) matching complete for some time
    - with and without space charge
  - 6D (transverse+longitudinal) matching more complex
    - necessary for ILC (among others)
    - only necessary for the most advanced (fully 6D!) simulations
    - without space charge case completed
    - with space charge case yet to be completed

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6D matching

$$x_f = M x_i$$

$$\sum x_f x_f^T = \sum M x_i x_i^T M^T$$

$$C \equiv \sum x_f x_f^T = \sum x_i x_i^T$$

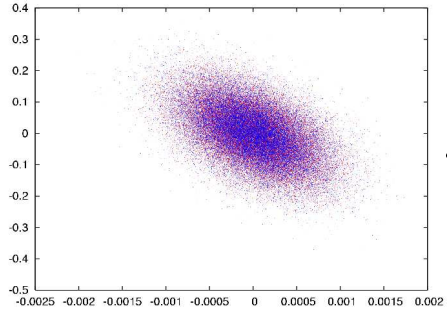
$$C = M C M^T$$

$$Me = \lambda e \Rightarrow \{\lambda_i, e_i\}$$

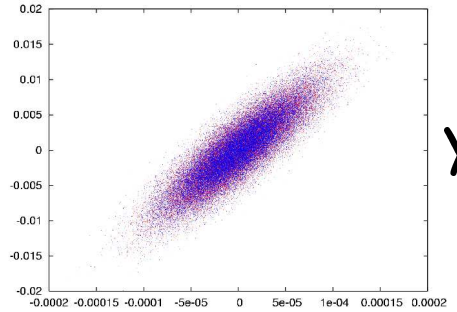
$$E_i \equiv e_i e_i^\dagger$$

$$C = \sum_i a_i E_i$$

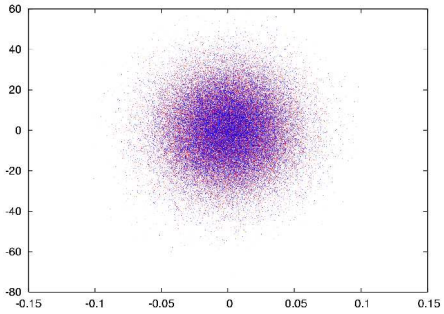
ILC damping ring



x,x'



y,y'



z,z'

Physics algorithms, continued

- More sophisticated RF system model
  - Basic RF already in Synergia
    - Detailed, slow RF available for over a year
    - Simple, fast RF recently added
  - Realistic model of Booster RF must go well beyond basics
    - Feedback loop couples RF to ramping of bending magnets through beam position monitors
      - Requires specialized main loop
      - Requires dynamic accelerator lattice configuration
    - Early losses occur while RF is ramping
    - Ideal application for Python-steered Synergia

Analysis/visualization

- Visualization tools will be easy to integrate with Python steering
  - Matplotlib and VTK have Python interfaces
  - We rely on Octave for off-line analysis
    - We have developed a large library of octave-based analysis tools
    - We already have a tool for Python-Octave integration: Octapy
- Advanced visualization has made a difference in our understanding of tune footprints...

Tune footprints

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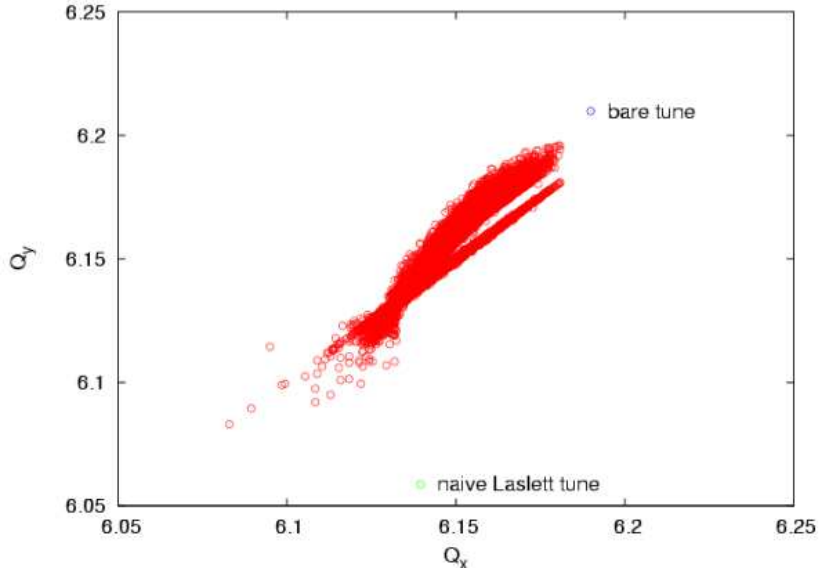
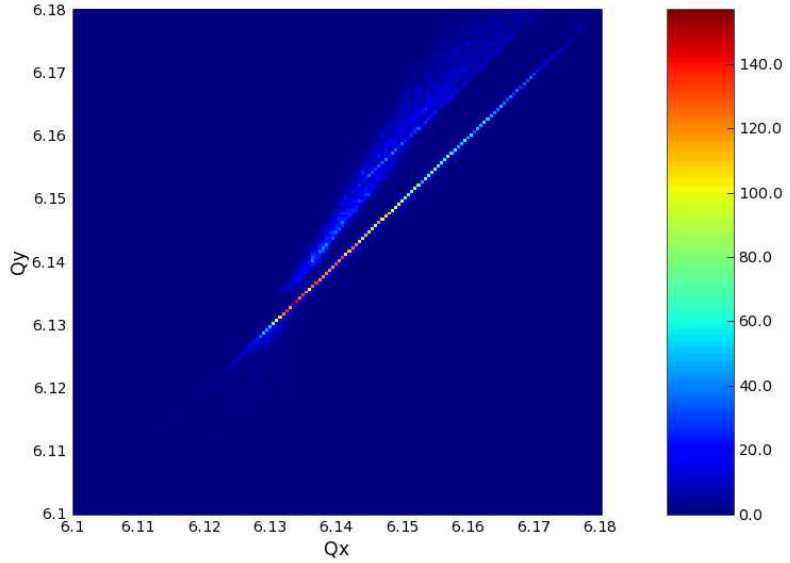
footprints for Montague resonance benchmark



simple



advanced

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Optimization

- Optimization is an important component in the future success of the project
  - Not a priority so far
    - Occasionally a bottleneck
  - Necessary to take advantage of next-generation computing resources
    - Scalability
  - IMPACT refactoring important for implementation
- IIT CS Professor Zhiling Lan has applied for a DOE young investigator grant to work with us on optimization

Resources

- Human
  - Panagiotis Spenztouris, Jim Amundson, Eric Stern
    - Fermilab, 2.5 FTE
  - Doug Dechow, Peter Stoltz, Scott Kruger
    - Tech-X SBIR II, Dechow at Fermilab
  - Dan McCaron
    - IIT accelerator physics grad student
  - Matt Drake
    - IMSA mentorship student, done April, 2005
  - Zhiling Lan and students (? - grant proposal submitted)
    - IIT computer science department

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Resources, continued

- Computational
  - Seaborg at NERSC
    - problematic for development
  - LQCD infiniband test cluster
    - Re-use of test machines from LQCD cluster research
    - Synergistic use of resources at Fermilab
    - Extremely useful for our project
  - Grid (?)

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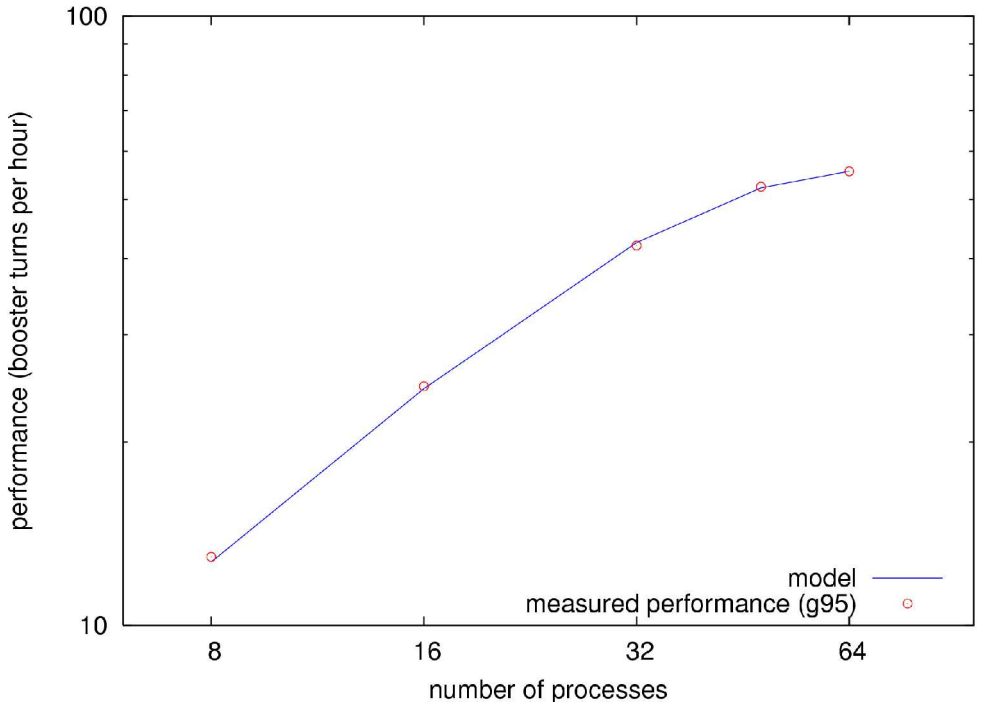
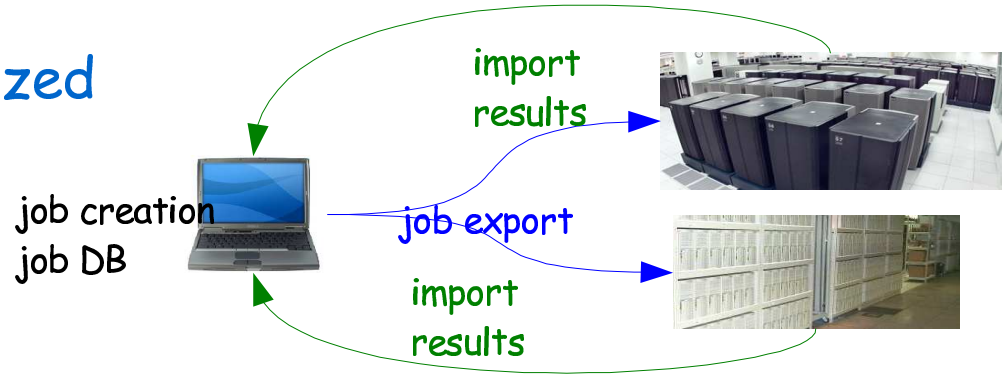
Infiniband cluster

- 32 dual 2 Ghz Xeons
- Infiniband networking
- Can sustain 2 medium-sized jobs (~40 booster turns/hour)
  - Booster problem sizes run from 20 -> 200 -> 2000 -> 20000 turns



Other computing resources

- Seaborg (NERSC)
  - 6000+ 300 Mhz cpus
  - Long batch queue latencies
  - Medium-sized jobs penalized
- Grid (?)
  - Grid-like job submission already in place
  - Have not yet pursued grid resources



- Grid will become more important as number of running jobs increases

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Summary

- Physics
  - Old topics (Booster) continue to improve
  - Related topics (Proton Driver) will be a natural extension
  - New topics (Tevatron, ILC damping ring) starting
  - Future topics (electron cooling/cloud) on the horizon
- Software/algorithm
  - Many refinements completed, steering/refactoring project underway
  - New physics topics to be integrated soon, optimization on the horizon
- Resources
  - New people
  - New (to us) computing cluster, other resources (grid) on the horizon